DESCRIPTION
OF THE
SYSTEMS INTERACTION PROGRAM
FOR
SEISMICALLY-INDUCED EVENTS

DIABLO CANYON UNITS 1 AND 2

August 15, 1980

Pacific Gas and Electric Company

Revision No. 3

[illegible]

Pacific Gas and Electric Company

Diablo Canyon Power Plant

Nuclear Project Department

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CHAPTER 1 INTRODUCTION

1.1 PROGRAM OBJECTIVE

The Systems Interaction Program for Seismically-Induced Events is to be conducted for the purpose of further eliminating the possibility of detrimental seismically-induced interactions between safety related equipment and nonseismically qualified equipment at the Diablo Canyon Power Plant. Detrimental interactions are those that could conceivably compromise the function of safety related equipment. Safety related equipment includes those structures, systems, or components which are required to safely shut down the plant, maintain the plant in a safe shutdown condition, and certain accident mitigating systems such as containment isolation, main steam isolation, fire protection hose reel system, and containment spray. The safety related structures, systems, or components are identified in the "Seismic Evaluation for 7.5M Hosgri Earthquake," Amendment 50 to the Diablo Canyon Final Safety Analysis Report. This program will establish confidence that when subjected to seismic events of severity, up to and including the postulated 7.5M Hosgri event, all Diablo Canyon Nuclear Power Plant structures, systems and components important to safety shall not be prevented from carrying out their required safety function by physical interaction with non-safety related structures, systems or components. Nor shall they lose the required redundancy to compensate for single failures because of such physical interactions.

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For the purpose of this report a target item is a structure, system or component important to safety. A source item is any structure, system or component which does not fall under this category. Henceforth, these will be referred to as target and source. In terms of relationship, a source is an item which affects a target.

The program will result in the identification and compilation of the following information:

a. Target Equipment to be evaluated for potential interactions with source equipment

b. Postulated failures

c. Postulated interactions

d. Analyses and resolutions to be handled in the field

e. Analyses and resolutions to be handled in the general office

f. Recommended plant physical or procedural modifications. | 3

1.2 PROGRAM SCOPE

The plant will be considered to be in a normal operating condition or in a state of shutdown, including refueling.

The program will include identification of target electrical, mechanical, fluid, pneumatic, and control equipment which are important to safety and which therefore must be evaluated for possible interactions with source equipment. A list of this required equipment will be prepared according to location in the existing plant fire zones. These fire zones are convenient spatial subdivisions.

The program will be implemented by the following activities:

A. Initial Office Activities

The First Task is the identification of all target equipment. All systems, subsystems and components will be identified together with associated information such as failure modes, etc. | 3

The Second Task is the identification of target equipment according to location in the existing plant fire zones, which provide convenient spatial subdivisions.

The Third Task is the preparation of detailed criteria.

Some of these criteria will be cast in a form suitable for use during the field walkdowns; others will be directed toward office evaluation and resolution.

Finally, a documentation data base, suitable for providing quality control for the entire systems interaction program, will be designed to ensure that all potential interactions are documented and resolved in a traceable and retrievable manner.

B. <u>Field Walkdown Activities</u>

1. Confirming Walkdown

After the target components have been identified and located during the initial office activity phase, an inspection will be conducted of each fire area to ensure that the data base to be utilized during the walkdown is accurate and complete.

2. Interaction Walkdown

A walkdown will be performed by an interdisciplinary team of experienced engineers. During the inspection, all possible interaction failure types will be postulated and documented | 3
using established criteria.

3. Inter-Compartmental Walkdown

An additional walkdown by the interdisciplinary team will then consider the effects of all possible inter-compartmental interactions.

C. <u>Technical Evaluation</u>

When data from the field walkdown are obtained, technical evaluations will be performed on all postulated interactions including field 3 evaluations.

D. <u>Modifications</u>

Unacceptable conditions as noted from the field walkdowns and validated through technical evaluation may require design modification to the plant. Such modifications, when required, will be implemented.

E. <u>Independent Audit</u>

An independent audit of the program will be conducted by the Quality Assurance Department.

F. <u>Independent Review Board</u>

A review board, independent of PGandE, will monitor the program progress, conduct independent audits, and report findings to the consultant managing the Review Board. The managing consultant will then report those findings to the Manager, Nuclear Projects for resolution.

G. <u>Final Report and Documentation</u>

A final report will be prepared which compiles all data from walkdowns, plant modifications and technical reports.

1.3 REPORT DESCRIPTION

This report discusses the Systems Interaction Program for seismically-induced events. Chapter 1 presents a brief introduction of the program. Chapter 2 presents the Organization and make up of the program teams.

Chapter 3 is a discussion of the Methodology of the Interaction Program. Chapter 4 presents the Criteria used for the program and Chapter 5 is a detailed description of the program.

1.4 REFERENCES

1. "Seismic Evaluation for Postulated 7.5 M Hosgri Evaluation" Amendment 50, Diablo Canyon Units 1 and 2, Pacific Gas and Electric Company, October 1977.

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CHAPTER 2 - ORGANIZATION

2.1 GENERAL ORGANIZATION

The Systems Interaction Program is administered by the Nuclear Projects Department under the direction of a project engineer. Personnel from various PG&E organizations are assigned to the project and take functional directions from the project engineer. Several consultants are used to supplement the PG&E organization and to provide specialized assistance. Figure 2-1 indicates the reporting relationships among consultants and PG&E personnel who fulfill key roles in the Systems Interaction Program.

2.2 RESPONSIBILITIES

2.2.1 Independent Review Board

The Independent Review Board (IRB) is responsible for reviewing any aspects of the System Interaction Program without restriction. Results of reviews will be submitted to the managing consultant, who interfaces with the Manager, Nuclear Projects. The Independent Review Board is made up of approximately five well established, experienced individuals from the professional and academic nuclear community.

2.2.2 Manager, Nuclear Projects

The Manager, Nuclear Projects, is responsible for the overall coordination of the program between PG&E and the consultant retained to manage the Independent Review Board. He also coordinates with the Manager - Nuclear Plant Operations, Manager - Station Construction, and Engineering Chiefs.

2.2.3 Systems Interaction Project Engineer

The project engineer reports to the Manager, Nuclear Projects and has the direct responsibility for the System Interaction Program. His responsibilities include the following:

a. Writing the System Interaction Program description.

b. Coordinating the efforts of consultants who are preparing the program, preparing implementing procedures, determining program inspection and evaluation criteria, and reviewing resolutions proposed by the Interaction Team.

c. Providing functional and technical direction to the Interaction Team.

d. Reviewing and approving the resolutions proposed by the Interaction Team.

e. Preparing interim reports and the final program report.

f. Communicating the activities of the Interaction Team and the results of the program to the Manager, Nuclear Projects.

g. Providing overall administrative direction for the program.

h. Initiating plant modification design changes resulting from the conclusions of the System Interaction Program analysis and resolutions.

The Project Engineer will use consultants to recommend technical decisions, assist with Nuclear Steam Supply System special considerations, provide administrative assistance, recommend resolutions, and provide analysis as needed. All consultants except as noted will report to the Project Engineer.

2.2.4 Interaction Team

The team members are required to have considerable experience on Diablo Canyon in their area of assignment and have been involved with the Diablo Canyon Project design, construction, or startup/operation. As PG&E acted as its own architect-engineer-constructor for the project, experienced in-house individuals are readily available. PG&E has also employed specialized consultants, architect-engineers, and NSSS suppliers to supplement the in-house experience.

a. The Interaction Team comprises the following discipline supervisors and their staffs:

   (1) Mechanical Systems

   (2) Piping Supports

   (3) Instrumentation and Control

   (4) Electrical

   (5) Civil/Structural

   (6) Heating, Ventilating, and Air Conditioning

   (7) Programs

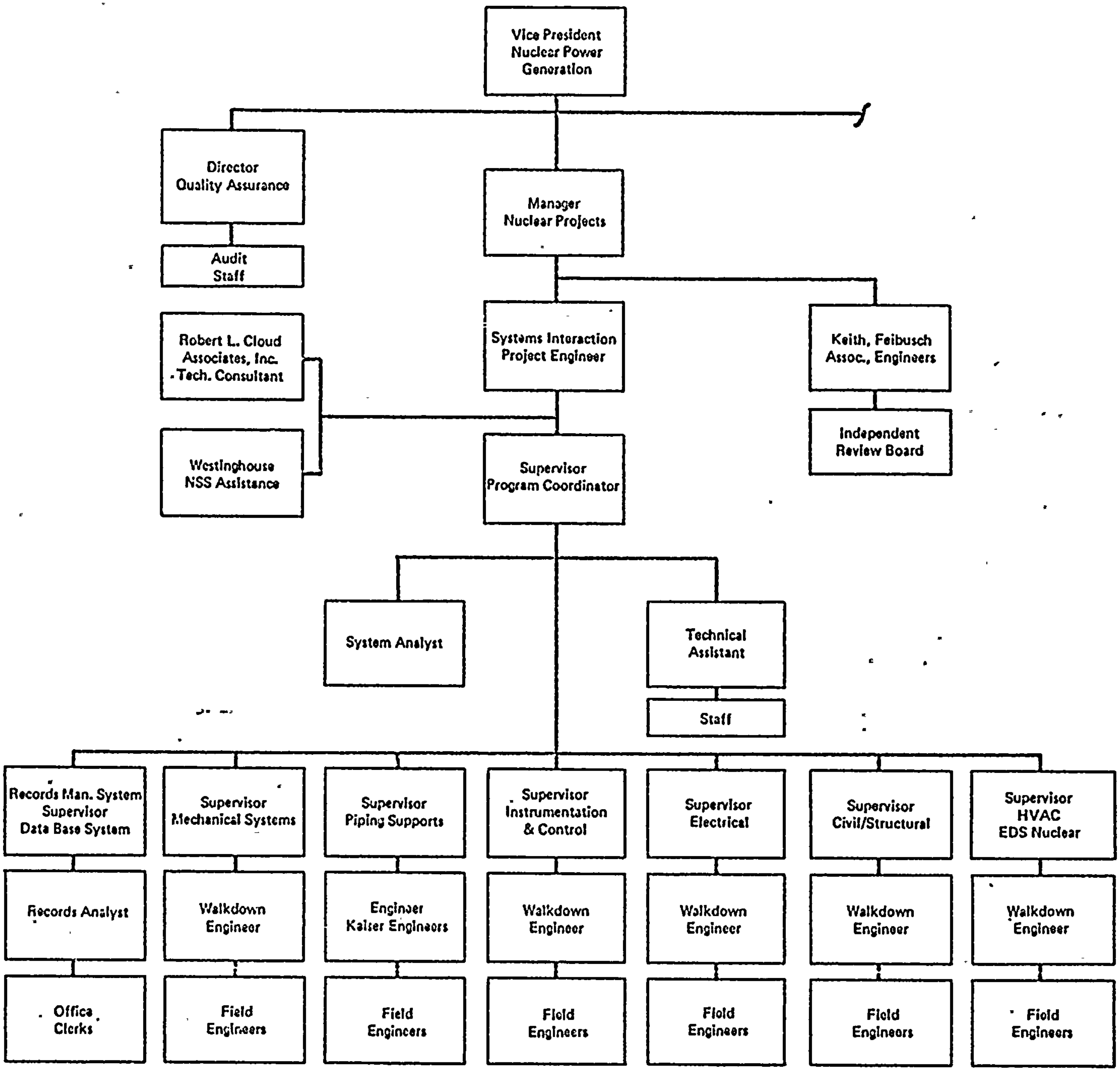
b. The discipline supervisors are selected from the staff of PG&E departments or from outside consultants, and are under the technical direction of the Engineering Discipline Chief. 3

Quality Assurance performs periodically technical audits of certain programs and will request technical assistance from other departments. For the System Interaction Program, an engineer from each engineering discipline has been furnished in order to perform an independent Quality Assurance audit. These engineers are experienced with the Diablo Canyon Power Plant but are not directly involved with the Systems Interaction Project and will take functional direction from Quality Assurance for the duration of the review and audit activities pertaining to the System Interaction Program. 3

The Director, Quality Assurance also supervises the Records Management Section which is not involved with the review or audit function. The Records Management Section is responsible to maintain records for Diablo Canyon in accordance with Title 10 Code of Federal Regulations Part 50 Appendix B Criterion XVII. The Records Management Section will microfilm essential data, records, 3 documents, and drawings associated with the System Interaction Program and will maintain a computerized index of the microfilmed documents.

Figu[illegible]-1

SYSTEM INTERACTION PROGRAM FUNCTIONAL ORGANIZATION



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SYSTEMS INTERACTION PROGRAM
CHAPTER 3 - METHODOLOGY

3.1 PURPOSE

This section describes the methodology and final documentation of the program.

3.2 GENERAL DESCRIPTION

3.2.1 Sequential Task Flow Diagram

The methodology is developed from the sequential set of tasks, or task flow diagram, as shown in Figure 3-1. Activities shown in Figure 3-1 and described in this report will be monitored by an Independent Review Board as described in Chapter 2.

3.2.2 Initial Office Activities

The first task of this program is the identification of all target structures, system or components. This will be accomplished by PG&E systems engineers in cooperation with systems engineers from the NSSS supplier and consultants. All individual target components will be listed. Most safety functions are performed by more than one system and this redundancy will be maintained, even though it was originally incorporated as protection against events. All functions, systems, and components will be tabulated in matrix form, together with associated information such as operability requirements. 3

The second task is the preparation of a list of target equipment according to location in the existing plant fire zones, which provide convenient spatial subdivisions. These spatial subdivisions will also provide a means for addressing intercompartmental interactions during the plant walkdowns.

The third task is to prepare detailed working criteria for:

a. Postulation of failures for source equipment

b. Postulation of effects due to interactions with target equipment as a result of these failures.

c. Technical evaluation of potential interactions

d. Resolution of interactions. Some of these working criteria will be cast in a form suitable for use during the field walkdowns; others will be directed toward office evaluation and resolution.

These criteria are defined in Chapter 4 of this report.

Finally, a documentation data base, suitable for providing quality control for the entire Systems Interaction Program, will be designed to ensure that all potential interactions are documented and resolved in a traceable and retrievable manner.

3.3 FIELD WALKDOWN ACTIVITIES

3.3.1 Confirming Walkdown

After the target components have been identified and located during the office evaluation phase, an inspection will be conducted of each fire zone to ensure that the data base to be utilized during the walkdown is accurate and complete.

3.3.2 Interaction Walkdown

A walkdown will be performed by an interdisciplinary team of experienced engineers as described in Section 2. During the inspection, all possible interactions will be postulated for source equipment that might affect the target system to be protected, using the criteria as described in Chapter 4. Consideration will be given to local equipment arrangements and geometry, and the possible results of these failures. The interaction team, after identifying all possible interactions between source and target equipment, will utilize the established criteria to determine if these interactions are credible. Once the field system evaluation has been completed the following information will be documented.

a. Location of the potential interaction

b. Components and systems involved in the potential interaction

c. The specific criteria used for the evaluation (which includes the type of interaction) 3

d. Recommendation of the interaction team. This may take the form of one of the following:

   (1) Finding whether or not an interaction occurs

   (2) Determine that, if interaction does occur, no safety function is impaired.

   (3) Recommendation that a physical modification be designed and installed.

   (4) Recommendation for further evaluation.

The Interaction Team will consider relevant failures to non-essential systems (e.g., loss of electricity and pressure) which may have an effect on the operation of target equipment.

When the Interaction Team enters a given fire zone, coded system drawings will be used as maps or charts to follow all systems that require protection. As each item in the system and its environment are inspected, it will be checked off the master list or matrix.

During the plant walkdown, each item of equipment on the list to be evaluated for interaction will be inspected by the Interaction Team. Each unit of source equipment in the vicinity of the item will be considered to fail by any or all of the specific mechanisms 3
listed in the criteria (Chapter 4). These mechanisms will be considered to act singly and in combination. When failure has been postulated, it will be possible during the inspection or, afterwards by offsite analyses, to determine interactions with the target equipment. All such interactions will be listed and evaluated using the established criteria as described in Chapter 4.

3.3.3 Intercompartmental Walkdown

The walkdown by the interdisciplinary team will consider the effects of intercompartmental interactions. All possible intercompartmental interactions will be identified and relevant data such as color coded system drawings, and location and relevant numerical data will be documented. The walkdown team will physically inspect all adjacent compartments that may have interaction effects. Items such as flooding, electrical, pressure, and dynamic effects will be considered. Further interaction effects that may be determined from evaluation of the data base information may require a second intercompartmental walkdown.

3.4 TECHNICAL EVALUATION

As the data from the field walkdowns are obtained, office-based technical evaluations will be performed on all conditions documented in the field. Analyses, testing, and historical experience, when applicable, will be used to determine if the field-noted condition is valid based on previously established criteria and will be documented on the computerized data base. If these office techniques demonstrate adequacy, no further activity (except documentation) will be required. The technical evaluation may indicate that changes in operating procedures or design modifications are necessary to resolve a potential interaction. 3

3.5 MODIFICATIONS

3.5.1 Design Changes

As potentially unacceptable conditions are noted in the field and evaluated to determine whether or not the condition is significant, engineering modifications may be required. Depending on the type of modification required and the provisions of applicable QA

requirements, the design will be accomplished either in the field or in the office. Analyses or tests used as the design bases will be as described in Chapter 4. All design, analyses, and construction work will comply with project quality assurance and quality control requirements (as defined in Chapter 17 of the FSAR and corporate quality assurance manuals).

3.5.2 Modification Walkdown

After required modifications have been completed, the systems modified will be checked in the field by the Interaction Team to assure that the modifications themselves have not resulted in unacceptable interaction conditions. Any unacceptable conditions will be resolved in accordance with the criteria of this manual.

3.6 INDEPENDENT AUDIT

The corporate Quality Assurance Department will direct a technical audit of the program. The independent audit team will include engineers from each of the engineering disciplines who are knowledgeable of the Diablo Canyon Plant, but are not involved with the Systems Interaction Program.

This team of engineers is responsible for the following:

a. Perform a sampling walkdown of representative compartments and their related intercompartmental interaction

b. Perform an audit of the previous intercompartmental walkdowns

c. Perform, on a sampling basis, separate analyses to verify that previous analyses were correct

d. Review program documents

e. Review completed modifications.

3.7 INDEPENDENT REVIEW BOARD

A review board independent of PG&E, as described in Section 2, will conduct a review of the program, which includes Systems Interaction walkdowns and a monitoring of the program's progress.

The independent review team will report its findings to the consultant managing the Review Board. The managing consultant will then report those findings to the Manager, Nuclear Projects.

PACIFIC GAS & ELECTRIC COMPANY
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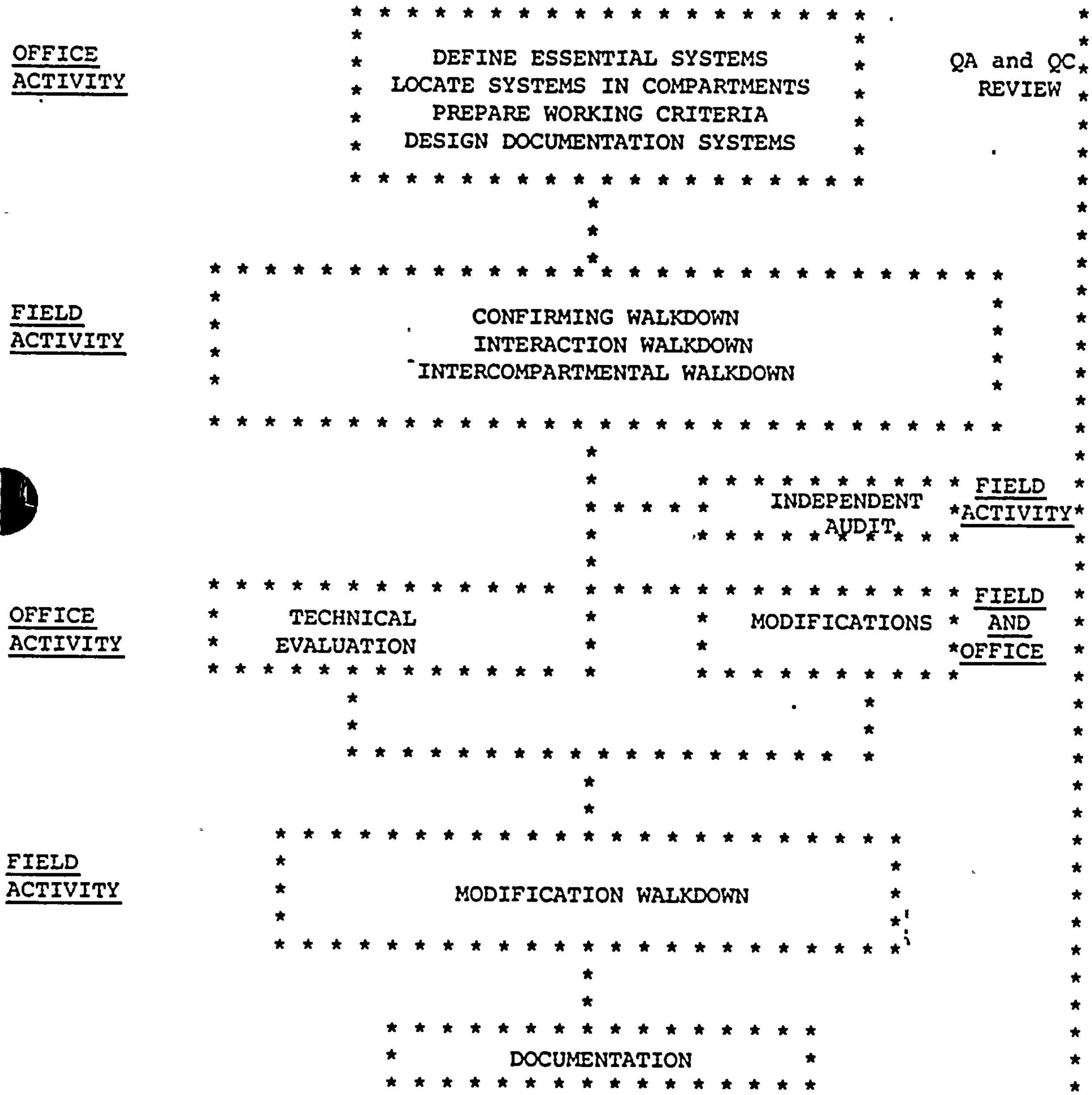
NUCLEAR PROJECTS DEPARTMENT

Figure
3-1
SEQUENTIAL TASK FLOW DIAGRAM
SEISMIC SYSTEMS
INTERACTION PROGRAM DESCRIPTION



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The following discussion delineates the criteria employed in the Diablo Canyon Nuclear Power Plant Systems Interaction Program for Seismically-Induced Events. It is organized along the lines of the program itself in that it proceeds from a fundamental guiding principle through identification of potential targets, sources, and interactions to evaluation and resolution of identified problems.

4.1 FUNDAMENTAL CRITERION

When subjected to seismic events of severity up to and including the postulated 7.5M Hosgri event, the program will demonstrate that the capability of all Diablo Canyon Nuclear Power Plant structures, systems, and components important to safety shall not be prevented from carrying out their required safety function by physical interaction with non-safety related structures, systems, or components. Nor shall they lose the required redundancy to compensate for single failures because of such physical interaction. 3

The preceding paragraph embodies the entire spirit and intent of this program. Several clarifications follow to aid in understanding.

Seismically induced physical interactions include any and all credible failures or adverse behavior of non-safety related structures, systems, or components. The credibility will be based on conservative technical judgement of experienced engineers. In the identification stage of the program the instructions are to identify any doubtful or controversial cases for detailed evaluation.

Seismic events are considered to include Hosgri magnitude ground motion, a tsunami, and the potential for full or partial loss of offsite power.

Interaction between two safety related items which are qualified to withstand the postulated 7.5M Hosgri earthquake is not deemed credible and is therefore not explicitly part of the program. If, however, in the course of the program, some design or construction oversight is observed, it will be evaluated and corrected.

Interactions which may be caused by other than seismic effects on non-safety related structures, systems, and components (such as human errors) have been and are being investigated in other studies and are not explicitly included in the Systems Interaction Program for Seismically-Induced Events.

Sources of interactions by pipe rupture of high energy and medium energy piping systems need not be considered in this program as a piping failure because previous safety programs have examined these piping systems and have made provisions to accommodate postulated pipe rupture.

Each postulated interaction will be formally resolved and documented. The resolution will be accomplished in one of the following ways:

- Simple interactions will be resolved in the field.

- Analysis will be performed to show the interaction will not occur or causes no damage to safety systems.

- A physical modification will be made to eliminate or mitigate the effect of the interaction. 3

In addition to the basic protection resulting from the implementation of the formal program, there is substantial margin available to cover other effects such as earthquake aftershocks or minor errors in design and construction. The degree of margin is discussed subsequently, but may be summarized as follows. Electrical failures due to open circuits or shorts

from cable failures are not expected since the conduit systems are Class I and the cable trays and supports remain essentially within the yield stress. The piping supports have an approximate factor of safety of 5 over catalogue values as indicated by a recent series of tests. The piping itself meets the requirements of ANSI B31.1 and will remain essentially elastic in vertical excitation. Horizontal motion of the piping is explicitly addressed by the program. All non-qualified valves with extended structure are explicitly considered in the program, as are overturning of tanks, cabinets and other equipment. 3

In addition to the above design and testing considerations, there is another category of margin resulting from the fact that material properties usually exceed specification values by 10 to 20%; and, when standard sizes and sections are used, calculated intermediate sizes are always rounded upward to the next heavier standard section. Damping values at Hosgri level excitation will be higher than design values and further, if plastic deformations are encountered, in the piping systems for example, the damping will increase by an order of magnitude.

The degree of excess margin will be apparent from the above together with the following discussion of criteria for postulating and resolving failures.

4.2 TARGET CRITERIA

The initial step in the program is the identification of potential targets. As defined in Chapter 1, any structure, system, or component important to safety is considered as a potential target and thereby may be susceptible to any detrimental effects of seismically induced behavior of nearby non-safety related structures, systems, or components. The portions of the fire protection system considered as targets are defined in the letter 3
of November 13, 1978 from Philip A. Crane, Jr. to John F. Stoltz, Chief, Light Water Reactors Branch No. 1, USNRC.

4.3 SOURCE CRITERIA

Sources of detrimental interactions are any non-safety related structures, systems, or components which, by their proximity to safety-related structures, systems, or components and the absence of defensible seismic qualification, may physically interact through mechanical, electrical, or fluid means to degrade the plant safety features. Sources are considered singly and in credible combination with other sources.

Structures, systems, and components important to safety are not sources by virtue of their seismic qualification.

4.4 INTERACTION CRITERIA

An interaction is identified whenever the seismically induced behavior of a source could lead to detrimental physical effects on a nearby target. Pairings of targets and sources are based on physical proximity or direct system connection. Then an assessment is made of the possible seismic behavior of the sources. An interaction is not identified by the field walkdown team if it can be established by inspection that no credible failure mode can be induced in the sources by earthquakes up to and including the postulated 7.5M Hosgri event which violate the fundamental criterion.

Instructions to the walkdown team are to identify doubtful cases for further evaluation. In general, interactions identified will be in one or more of the following categories:

a. Contact between a source and a target that would compromise operability of the target.

b. Fluid leakage from one or more sources that would degrade the environment of the target component.

c. Contact between a missile generated by a source and a target that would compromise the pressure boundary of the target component.

d. Contact between a missile generated by a source and a target that would compromise operability of the target component.

e. Secondary or chain interaction caused by any of the above interactions.

The following criteria provide guidance both to the walkdown team and to subsequent engineering teams for evaluation of the credibility of hypothetical interactions and their effects.

4.5 EVALUATION CRITERIA

The evaluation of seismically induced systems interactions and their effects on plant safety rests heavily on experienced engineering judgment. It is judgement which permits such a program to be accomplished since without some limits based on credibility or probability, the program would expand to an impossible magnitude. The following criteria supplement and exemplify the judgment element of this program. They do not replace the need for experienced engineers with design and operational experience to perform the evaluation, nor were they so intended. As discussed in Chapter 2, reliance is placed on assigned engineers in various relevant disciplines applying their knowledge and experience in evaluating the problems. These engineers were given the following criteria as guidelines to benchmark their evaluation. They were instructed not to be narrow in interpretation.

4.5.1 Evaluation of Sources

Potential sources are evaluated as part of the program to determine if seismic events can credibly lead to detrimental interaction with safety related structures, systems, and components. Following are three possible outcomes of this evaluation:

a. Seismic events will not lead to interaction because of defensible seismic qualification of the sources by analysis, test, or experience with the same or similar items.

b. Seismic events may lead to damage or failure of the sources, but the credible failure modes are no threat to the safety function of the target.

c. Seismic events may lead to a credible failure mode of the source which has the potential to cause adverse interaction.

The following criteria provide minimum guidance for evaluation of sources. They are tabulated by discipline with the generic code listing used in the program data base for convenience.

4.5.1.1 Structural Source Evaluation

All structural sources are evaluated by the single criterion:

CF1 - Any non-safety related structural element determined to be a potential source will be assumed to fail, unless seismic qualification by analysis, test or comparison to similar previously qualified elements has been performed to ensure integrity.

4.5.1.2 Mechanical Source Evaluation

The following is a set of failure modes for mechanical equipment and piping systems which must be considered when evaluating potential sources in these categories.

In addition to the specific failures below, complete loss of power for all source equipment and control has been postulated. Relative motion between the source and target are considered during the walkdown examination.

MF1 - Overturning of tanks, pumps, filters or other unsupported equipment where the center of gravity location as measured from the base is longer than one-half the base width in all directions. Each direction will be evaluated independently.

Overturning is not considered where the distance from the base to the center of gravity is small. Further conservatism is obtained because mechanical equipment is held down by bolting, brackets, etc. Valves are considered under MF2.

MF2 - Failure of valve and vertical pump motor and/or 3
operator upperstructure to body junctions is assumed for the following cases:

a) All motor an air operated valves.
b) All pumps and gear-operated valves with upperstructure lengths greater than 12".
c) All handwheel-operated valves with upperstructure masses greater than the body/bonnet mass.

A sizable number of valves with heavy upperstructures must be anticipated. Many of these had to be specially
qualified by testing or bracing for Class I service even 3
though not classified as Class I.

Evaluations will be performed for situations in which valves with significant upperstructures could violate the fundamental criterion if they fail structurally.

All power operated valve upperstructures are assumed to fail. Upperstructure failure of some gear and handwheel-operated valves as well as vertical pumps is assumed, although the number of cases considered should be small and any reanalysis should verify the structural adequacy of the as-installed configuration. Seismic analyses have shown that upper-structure stresses are generally low. The criteria shown is a conservative basis derived from considerations of these analyses. 3

MF3 - Lateral deflection at top of tanks and vessels of one (1) inch per foot of tank or vessel height shall be assumed to allow for sloshing. This failure involves tank movement only. Fluid loss will not occur under this criteria. See criteria MF4 for loss of fluid.

MF4 - Support failure for vessels of total mass greater than 100 lbs. resulting in toppling of the structure and loss of fluid for the following cases:

a) All vessels supported on legs.
b) All vessels supported on unstiffened saddles of one-half inch (1/2") thickness or less.

Tanks are supported in a variety of ways, typically on legs, cylindrical skirts or saddles. Whereas shell buckling (criterion MF3) results in tank deflection, support failure could violate the fundamental criterion by allowing tanks to topple. Support failure is restricted to thin section skirts or saddles and to all leg supports. Heat exchangers with attached piping will be treated as a special situation, criterion MF6. Anchor bolting integrity is generally not compromised, however suspect configurations are treated as special situations, Criterion MF6.

MF5 - All pump anchorages are assumed to fail for all non-bedplate mounted pumps, resulting in displacement of the pump.

Most pump assemblies are securely mounted to bedplates. This failure mode is listed for completeness. Operability of Class II pumps is not an issue.

Pump support bolting are assumed adequate for bedplate mounted pumps. All non-bedplate mounted pump supports, such as pedestals, cases, brackets, etc. are assumed to fail. Motor drivers will topple if support failure is postulated. An evaluation is made as to the possible consequences of pump or motor displacements due to support failure. 3

MF6 - Extraordinary or unusual situations not otherwise covered that require resolution by analysis, test, or other suitable means. 3

Postulated failures of other miscellaneous mechanical equipment are treated on a case by case basis.

4.5.1.3 Electrical Source Evaluation

Several categories of failure type must be considered with regard to seismic effects on electrical sources (equipment and cabling). They are discussed briefly in the following section.

a. Electrical Equipment

EF1 - Overturning of cabinets, transformers, switchgear or other unsupported equipment where the center of gravity location as measured from the base is longer than one-half the base width in all directions. Each direction will be evaluated independently.

The same considerations discussed in regard to overturning of mechanical equipment apply to electrical equipment, i.e., overturning is assumed for cases where the distance to the center of gravity is significant compared to the base width.

EF2 - Support failure resulting in overturning of the structure for all floor mounted electrical equipment greater than 100 lb. total mass.

Support failures are assumed for all floor mounted electrical equipment greater than 100 lb. total mass. Qualification of such equipment by similarity to Class I equipment can be accomplished in many cases.

EF3 - Failure of equipment mounting for cases where wall-mounted electrical equipment with extended unsupported structures greater than 12" in length and exceeding 50 lbs. total mass are present.

EF4 - Extraordinary or unusual situations not otherwise covered related to electrical equipment use this code in the data base. This is the category where the observations in the field bring to light interactions other than the mandatory generic types above, such as equipment structural failures. These failures are treated on a case by case basis.

b. Raceways

RF1 - Failure of supports and collapse of cable trays that have vertical supports with a spacing that exceeds eight (8) feet. Cables are not assumed to fail on the basis of historical experience within the PG&E system and elsewhere.

All cable trays at Diablo Canyon are designed and supported by vertical supports required at a maximum spacing of 8 feet. This requirement very conservatively requires that a failure of vertical support be assumed if the specified spacing requirements are not met. If the spacing requirements are met, the support is very conservative and no failure need be assumed. Conduits are, in general, safety related qualified components or are comparable to safety related conduits 3

and supports by virtue of use of the same designs and hardware and therefore are assumed not to fail. Any postulated failures of non-qualified conduit is treated as a special situation, criterion RF4. 3

RF2 - Longitudinal displacement (in direction of tray) equal to 5% of the length of the vertical support for all cable trays that do not have one longitudinal support every 20 feet.

The support standard provides for longitudinal support spacing of 20 feet. This is a conservative requirement, and when followed will support the trays adequately in the longitudinal direction. This criterion will conservatively account for possible interactions due to longitudinal motion of cable trays. The most widely used longitudinal support is a rigidly welded 4 x 4 x 3/8 in. angle iron.

RF3 - Lateral displacement (perpendicular to direction of tray) equal to 5% of the length of the vertical support for all cable trays with support systems that:

a) have no lateral bracing or,
b) exceed the maximum length requirements specified in Table 4-5-4.

It is unnecessary to consider lateral displacement of the cable trays for those trays with suitably spaced supports that are laterally braced, which covers the preponderance of trays in the plant. If lateral bracing is absent or support spacing or support lengths do not satisfy requirements listed in

Table 4-5-4, then the above (RF3) conservative lateral displacement must be considered. The allowable strut lengths are based on 50 #/ft. of cable, 1.5 g floor acceleration, and initial yielding of the supports using specified properties. 3

RF4 - Extraordinary or unusual situations with raceways not otherwise covered.

Unusual conduit or cable support failures and cases where cable severence appears possible due to seismic effects are examples of special situations requiring further investigation on a case by case basis.

Interactions due to unwanted energization or short circuits will be minimized for several reasons. All Class I power cable is encased within protective conduit and the entire assembly is qualified for seismic loads. As discussed herein, all safety related conduits are considered targets in this interaction program and are protected from interactions with unqualified equipment.

Of equal or greater importance is the fact that all cable tray supports at Diablo Canyon, although not seismic Class I, are nevertheless very conservatively designed. All cable tray supports are within the yield stress for the Hosgri earthquake loads. Further, an exhaustive series of dynamic tests* on cable tray systems showed that strut supported cable trays with supports and spacing of the design used at Diablo Canyon will not fail in an earthquake of Hosgri magnitude. 3

* "Bechtel Cable Tray and Conduit Raceway Seismic Test Program," ANCO Engineers and Bechtel Power Corporation, December 1978.

In addition to testing the structural strength of the cable trays and supports, tests were conducted for open circuits and grounds. In over 2,000 individual dynamic tests, none were discovered. Therefore, it is reasonable to expect that the cable systems will retain electrical integrity in an earthquake of Hosgri magnitude. 3

4.5.1.4 Heating, Ventilating and Air Conditioning (HVAC) Source Evaluation

Five generic failure mode categories are considered for HVAC sources. The following is a brief discussion of each of these categories.

HF1 - It has been determined by analysis that for the identified spacing of vertical supports, the duct/support/anchorage system will not fail. For this evaluation, ducts supported vertically at spacings exceeding the following are assumed to fail:

Rectangular ducts with the larger dimension 60" and smaller.	8' - 0"
Rectangular ducts with the larger dimension over 60".	4' - 0"

Round ducts up to 60" diameter.	6' - 0"
Round ducts over 60" diameter.	4' - 0"
Vertical ducts - any size.	6' - 0"

HF2 - Evaluation of the duct/support/anchorage system has identified acceptable lateral support spacing. Ducts supported laterally at spacings exceeding these identified acceptable values are assumed to fail. The spacing is as follows (lateral bracing resulting from duct geometry, i.e., 90° bends or similar, will be considered as acceptable lateral support):

Rectangular ducts with the larger dimension 60" and smaller.	25' - 0"
Rectangular ducts with the larger dimension over 60".	45' - 0"
Round ducts up to 60" diameter.	35' - 0"
Round ducts over 60" diameter.	50' - 0"

HF3 - Evaluation of the duct/support/anchorage system has identified acceptable longitudinal support spacing. Ducts having longitudinal supports exceeding this following spacing are assumed to fail:

Rectangular ducts with the larger dimension 60" and smaller.	30' - 0"

Rectangular ducts with the larger dimension over 60".	50' - 0"
Round ducts up to 60" diameter.	50' - 0"
Round ducts over 60" diameter.	100' - 0"

HF4 - Analysis has shown that ducts which are supported such that failure is not possible (evaluation with respect to HF1, HF2, and HF3) can deflect the amounts identified. Safety related equipment located nearer to the ducts than the following distances are assumed to interact:

Rectangular ducts with the larger dimension 60" and smaller.	1"
Rectangular ducts with the larger dimension over 60".	2"
Round ducts up to 60" diameter.	1-1/2"
Round ducts over 60" diameter.	2-1/2"

HF5 - Failure of In-line HVAC equipment will follow the source evaluation criteria for Mechanical equipment. Support failure resulting in tipping, falling, sliding or overturning may occur. Stress analysis will be conducted on a case by case basis when and if required. Overturning will be assumed possible when the distance as measured from the base to the center of gravity is more than one-half the width of the base. Each direction will be evaluated independently.

HF6 - Extraordinary or unusual situation as regards HVAC sources not otherwise covered.

During the walkdown effort, extraordinary or unusual situations could possibly arise. Resolutions of special situations will be conducted as necessary on a case by case basis. Stress analysis will be used as required.

4.5.1.5 <u>Piping System Source Evaluation</u>

Piping at Diablo Canyon was designed to meet the requirements 3
of the ANSI B31.1 piping code.

The following criteria serve to guide the walkdown engineers in their evaluation of whether failure will be assumed for piping, piping components and pipe support hardware. These failure modes establish the source of an interaction. Each of these failure modes must be considered to determine the probability of a source/target interaction. A discussion is provided for each failure mode to evaluate the potential for failure.

PF1 - Circumferential breaks are assumed for threaded 3
(greater than or equal to 4" NPS) and mechanically coupled (all pipe sizes) pipe.

Threaded pipe is more susceptible to seismic failure than welded pipe. Threaded pipe cannot withstand the same amount of pipe deformation as welded pipe can. Threaded joints have less ductility than welded joints, especially in the pipe sizes 4" NPS and larger. Complete pipe
severance shall be assumed for pipe sizes 4" NPS and larger. 3

In the case of pipe sizes smaller than 4", the need to evaluate for complete severance is not required. Small pipe is more flexible relative to its heavier fittings, has less strain in the pipe wall for a given deflection, and has less inertial force relative to the cross-sectional area of larger pipe. 3

All mechanically coupled pipe such as plain end victaulic couplings are susceptible to seismic failure. Excessive deformations and seismic loads cause complete severance at the coupling and the consequence will be considered. 3

PF2 - Bolted flange separation is assumed due to flange bolt strain resulting in fluid leakage at:

a) Fixed locations such as pipe restraints and equipment nozzles.

b) Flange locations which deflect excessively: see criteria PF5.

Excessive deformation or seismic loads can cause flange bolts to stretch. Also, a small permanent strain in the flange bolt can permit a disproportionately large lateral displacement of the piping system. It is therefore assumed that a properly designed flanged joint will separate, and consideration shall be given for leakage and pipe deflections resulting from flange separation.

PF3 - Failure of fixed-end rod type pipe supports is assumed due to lateral displacements of the piping.

Rod hangers of piping systems were reported to have failed on certain heavy power piping in the Great Alaska Earthquake. The rod hangers that failed were short fixed-end threaded hangers that concentrated the strain in the fixed end and broke. (Incidentally, the hangers broke, but the piping did not.) Bending moments at the fixed end of the rod support can cause failure provided that sufficient lateral restraints are not provided.

Consideration shall be given to the effects of pipe deflections resulting from the failure of fixed-end rod type pipe supports as a source of pipe interactions.

PF4 - Failure of vertical supports (rods, spring hangers, clamps, U-bolts, etc.) is assumed for piping support systems that do not meet the pipe support spacing requirements as shown on Table 4-5-2.

The vertical pipe support spacing requirements shown on Table 4-5-2 are the recommended spacing for dead weight given in B31.1, Power Piping Code. Piping support components are selected to meet the dead weight load requirements for this spacing, include a safety factor of approximately five, and are assumed to withstand seismic loads without failure. Failure of pipe support components with support spacing in excess of the recommended spacing is assumed and consideration shall be given to the pipe deflections caused by the pipe support failure. 3

When concentrated masses are included in a piping system, supports, as designed, are provided with extra strength, unsupported spans are shortened, or both. It will be verified during plant walkdowns that support systems are strengthened at least proportionate to the additional mass, otherwise the supports will be assumed to fail.

Several example analyses of limiting cases will be presented in the final report to show the conservatism of pipe support systems. 3

PF5 - Lateral displacement of pipe is assumed in the amount given in Table 4-5-1 for pipe with lateral support spans equal to or less than the amount given in the same table.

It is not unusual for nonseismic piping to be adequately designed and supported for dead weight and thermal effects, but to have little resistance to lateral loads which can be imposed by an earthquake. In an earthquake the piping can, therefore, undergo large swaying or lateral motions. In fact these motions historically have not caused the pipe to fail, but for the present program it is reasonable to consider the possibility of interaction with safe shutdown systems. The entire pipe span will be assumed to deflect by the amount shown in Table 4-5-1.

Consideration shall be given to lateral pipe displacements in the amount given in Table 4-5-1 as an envelope of pipe displacements to guide the engineer to anticipate interactions by pipe contact. The location of pipe restraints on the source piping with respect to the target shall serve to reduce the lateral displacement only when sound judgment can reasonably permit. Use criteria PF6 to adopt this displacement and span criteria for offsets and valves within the span length. Spans greater than those shown in Table 4-5-1 will be treated as a special situation, Criterion PF8.

PF6 - Lateral displacement of pipe is assumed in the amount given in Table 4-5-1 for pipe spans with concentrated masses (except flanges and flow elements). This applies if both of the following conditions are met:

a) Concentrated mass located within the middle 50% of the span.

b) Concentrated mass greater than equivalent weight of 3 diameters of pipe.

Concentrated masses such as valves located within a pipe span lower the span resonant frequencies and raise the resultant deflections. Additional restraints are usually located near concentrated masses to limit deflection. Concentrated mass situations where the span length exceeds the amount specified in Table 4-5-2 will be treated as a special situation, Criterion PF8. 3

PF7 - Leakage area equal to one flow area is assumed to develop gradually, at all threaded or mechanically coupled joints (except flanges) of pipe 4" NPS and larger.

Leakage is assumed to occur. Previous analyses* have been performed regarding the capability of the plant to cope with a flooding situation. Special flooding scenarios encountered which were not covered by the flooding 3

* Diablo Canyon FSAR Subsections 8.3.2, 9.2.1, 10.4.5, 3.6, and 10.4.6; "Seismic Evaluation for Postulated 7.5M Hosgri Earthquake," Subsection 5.1.2; Letters of December 28, 1979 and September 14, 1979 from Phillip A. Crane to John F. Stoltz, Light Water Reactors Branch No. 1. 3

analysis will be addressed as special cases. Sudden pipe breaks that result in pipe whip are not expected. A high energy line break protection program has been previously implemented as discussed in Paragraph 4.1. 3

PF8 - Extraordinary or unusual piping situations not otherwise covered.

It is expected that the experienced engineers carrying out this program will identify some cases which do not fit the other generic categories or represent combinations of failure modes. Such cases are to be evaluated as the circumstances dictate. For example, longitudinal (axial) displacement of pipe will be treated on a case to case basis.

The classes of interactions defined in the preceding paragraphs are expected to include essentially all credible seismically induced physical interactions. It is doubtful that interactions of types other than those described will occur. There are substantial amounts of margin in the design of the piping and hanger systems both due to the inherent resilience of piping and the requirements of the ANSI B31.1 Code for Power Piping. All non-seismic piping in the plant meets the requirements of the B31.1 Code.

Most of the non-seismically qualified piping in the plant had hanger support locations chosen by means of the hanger spacing tables of the code which is reproduced as Table 4.5.2 herein. These span lengths are chosen to limit the dead weight bending stress to 1,500 psi. On a simplistic basis, a 10 G earthquake loading would produce on 15 ksi bending stress which is less than the yield stress of the predominantly carbon steel pipe. Dynamic effects would alter this example to some degree, but it can be seen that the piping is hung in a very conservative manner. 3

As would be expected, power piping has performed well in past earthquakes. In a recent study of the performance of B31.1 piping in actual earthquakes,* no significant

* Cloud, R. L., "Observations on the Behavior of Piping in Past Earthquakes," ASCE Specialty Conference on Civil Engineering, Knoxville, Tennessee, September 1980.

failures of piping were found. This study included several fossil fueled power plants with piping designed to the B31.1 criteria. Certain of these plants sustained severe ground motion of about 0.5 G. There is substantial margin in this category of piping, and seismic induced failures of B31.1 piping are not expected at Diablo Canyon.

The pipe support systems or hangers similarly meet or exceed the B31.1 requirements. Pipe hangers and supports were either fabricated structural steel or Grinnell pipe hangers. The structural steel hangers are in general, substantially over-designed. Regarding the Grinnell pipe hangers, PGandE conducted a test program* to determine the true margins of Grinnell U-bolts, the most widely used non-seismic pipe supports. Other tests** have been done on anchor bolts. In both cases, the failure loads were generally found to be on the order of a factor of 5 above the catalogue load. These results are consistent with the philosophy of the MSS 58 and 69 standards and constitute a satisfactory amount of design margin. 3

The available margin in the non-seismically qualified piping and pipe supports will be demonstrated by analyses of several worst case examples of piping considered in the program. It will be shown in the final report that seismically induced primary strains, E_p^s will satisfy the following criteria or the more conservative Hosgri evaluation criteria.

* "Pacific Gas and Electric Co., Station Construction Department, Diablo Canyon Project" U-Bolt Test Program, October 1978.

** "Generic Response to USNRC I&E Bulletin No. 79-02 Summary Report" TR-3501-1 and Supplement. TR-4121-1 Teledyne Engineering Services, August 1979.

$$E_p^s \leq 1/4 \; E_{ue}$$

E_{ue} = minimum specified uniform elongation in the tensile test

E_{ue} is illustrated on the material stress-strain diagram. 3

4.5.1.6 Instrumentation and Control, Source Evaluation

Capability of instrumentation and control equipment to physically interact with and inflict damage upon other power plant equipment is limited because of the size of the I&C equipment relative to potential targets. The only two categories defined for direct physical interaction potential from I&C sources are discussed below.

IF1 - Failure of instrument extended proportions greater than 12" in length which exceed 50 lbs. total mass.

Most instruments are low in mass and insensitive to seismic inertial loads. In some cases, significant extended proportions exist for transmitters, air plenums, etc., but few such configurations are found in the plant. Class I instruments have been seismically qualified by tests which in many instances can be extended to Class II instruments by similarity. For the most part, few structural failures of instruments are expected.

IF2 - Extraordinary or unusual I&C situations not otherwise covered.

Any other structural failures of instruments such as support failures, large deflections, etc. will be treated on a case by case basis.

4.5.2 Interaction Effects Evaluation Criteria

Once an interaction is identified as sufficiently credible to require more evaluation than can be done from inspection, it must be resolved in an acceptable manner and the resolution documented. Interactions considered are direct physical interactions such as target impact from a falling or moving source. Some typical interactions are listed below.

Mechanical:

- impact from vibrating bodies
- impact from falling bodies
- pipe whip
- missiles 3

Electrical:

- unwanted open circuit (loss of power control)
- unwanted closed circuit
- unwanted energization

Pneumatic:

- loss of pressure (loss of control)
- unwanted pressurization
- jet impingement
- hostile gas

Hydraulic:

loss of pressure

(a) loss of control

(b) loss of lubrication

unwanted pressurization

jet impingement

flooding

hostile fluids

Environmental

elevated temperatures

steam

radiation

Environmental effects related to any pipe break condition, including temperature, pressure, jet impingement and flooding have been included in previous studies and referenced in the Diablo Canyon FSAR.

The interactions may also be indirect as in the case where a source may fail in a manner such as to damage another piece of non-safety related equipment which then and only then could interact detrimentally with a target. 3

Interactions are evaluated for their impact on the required safety functions and redundancy of identified targets. The results of the evaluation will then determine the method of resolution. In order of preference, the following are categories of acceptable methods of resolution of identified interactions.

a. Target Operability Evaluation:

The first approach to resolution is to show that the target's safety function is not impaired. This may be accomplished by studying the means by which impairment occurs and the possible extent of the impairment. For example, a pneumatically operated valve may be required to close during shutdown, but falling equipment could sever the air line so air supply to the operator is lost. If the valve is a "fail open" type, then shutdown capability is compromised, but if the valve is a "failed closed" type, then shutdown capability is not compromised even though the air supply is lost. In this example it is also necessary to consider consequences of crimping the air line, as well as the effect of a lost air line.

This example is typical of the reasoning process that is necessary in the evaluation of each interaction. A substantial degree of engineering judgement is, of necessity, expected to be used. Decisions based on judgement, along with the rationale, are documented.

b. Source Behavior Evaluation:

The second approach to resolution is to perform a more careful evaluation of the source under seismic excitation. If tests, analysis, or applicable experience can be developed to demonstrate that the item in question is qualified to withstand the postulated 7.5M Hosgri event, the interaction can be declared resolved on the basis that it will not credibly occur. Tests and analyses will be done using the methods and criteria employed for safety related equipment in the "Hosgri Report." The test results and analysis will be documented and retrievable on the PGandE Records Management System. All sources are 3

identified and resolved individually. Identification and resolution of indirect or chain-reaction source events shall use individual source failure criteria of each component source.

3

c. Modification:

If resolution is not possible by analysis or by test, the Interaction Team will recommend physical modifications to prevent detrimental interaction. The range of possible modifications includes guard structures, protective covers, restraining structures, and seismic stops. The criterion is to prevent impairment of function. If a modification is necessary, the most appropriate method and design will be chosen.

d. Change of Procedures:

The last method of resolution is by reordering the operating procedures or defining alternate means of providing the required safety functions. This option, although an unlikely choice, is still a possible solution.

Except for those interactions that require complex analysis, presently though to be few, the evaluation and resolution of the postulated interaction will be made at the site by the Interaction Team. The evaluation and resolution methods are discussed below in more detail.

4.5.2.1 Evaluation of Direct Interaction Effects 3

Where evaluation is directed to showing that the safety function of a target is not impaired by an identified direct interaction, the following guidance has been established. For cases not covered, criteria are developed and documented to provide an analagous level of rigor to the guidance herein provided.

a. Direct impact of missiles or falling objects on structures and components can be evaluated using the criteria of sections 3.3.2 and 3.5 of the Diablo Canyon FSAR and in ANSI Standard N660, Plant Design Against Missiles. In cases of small low energy objects impacting large steel encased equipment it may be possible to show no damage by inspection. Care must be taken to consider such appurtenances as instruments, power connections, cooling and lubrication connections.

b. Direct impact of missiles or falling objects on HVAC ducts can be evaluated using the values in Table 4-5-3. If the maximum impact energy is less than the tabulated value of kinetic energy, no loss of function need be assumed. 3

c. Dynamic effects of breaks in piping can be evaluated using the criteria in section 3.6 of the Diablo Canyon FSAR. 3

d. Flooding effects of broken or leaking pipes are evaluated using the criteria of appendix 3.6A of the Diablo Canyon FSAR.

e. Environmental effects of broken or leaking piping, tanks, etc. are evaluated by comparison of the estimated environment with the target's qualification profile. Helpful criteria and data are contained in section 3.11 of the Diablo Canyon FSAR.

4.5.2.2 Evaluation of Indirect Interaction Effects

Two types of indirect interaction are considered; chain-reaction failures and degraded operation.

For the chain-reaction events, the criteria for evaluation are the same as for the direct interactions and are successively applied to each member of the chain. It must be remembered that each step in chain scenarios has an associated probability less than one and that judgement must be applied to eliminate very unlikely sequences.

In order for the plant to safely shut down, it is necessary for the required safe shutdown valves and drive elements to operate in the required manner, or fail in the required position. For this to occur, their control systems must remain intact after a seismic event, or else be damaged only in such a way as to fail in the design failure mode. For example, if an air operated valve is required to fail in a certain mode, the design is such it will go to that failure mode on loss of air. If, however, the air line between the control device and the valve were to be impacted during a seismic event, the line might be pinched, and prevent the venting of air and thus the proper failure mode. 3

In electrically operated devices, a non-qualified component could impact the signal cable and cause damage which would adversely affect proper operation.

The walkdown procedure will assure that process tubing, instrumentation, and electrical cables up to the cable trays will be protected from the following:

1. Damage due to inadequate support.

2. Damage due to postulated interactions.

Evaluation of this type of indirect interaction will be handled by considering the above as targets.

The following failures are not considered in this review because they were considered in the original design:

1. Failure of the supports for required electrical conduits. 3

2. Failure of required instruments due to inadequate seismic qualifications of the instruments themselves.

In the event that questionable indirect interactions are identified which are not readily evaluated to be acceptable, the resolution then becomes one of modification such as redesign or replacement of the source equipment or the rerouting or upgrading of control and electrical wiring and/or process and air tubing.

No impairment of the integrity of the cable within the cable trays is expected for several reasons. As discussed previously under criterion RF4, the trays and supports are generally within the elastic range during the Hosgri earthquake. Also extensive seismic testing on comparable cable tray systems showed cable integrity is not jeopardized by seismic shaking.

In general, cable trays are mounted near the ceilings above potential interaction sources. In addition all 3 high and medium energy lines are restrained from pipe whip, which eliminates the chance of impact from high energy lines.

4.6 MODIFICATION CRITERIA

Modifications may be required to resolve identified seismically induced systems interactions. These modifications may be any of the following:

a. Modification of the source to eliminate the adverse seismic behavior by bracing, supporting, or reinforcing the source component.

b. Shielding or relocation of the target to preclude the physical interaction.

c. Modification of the target to permit retention of the required safety function in spite of the interaction.

The criteria for structural or mechanical modifications are the same as documented for safety related structures and equipment in the HOSGRI Report.

For relocation or modification of non-safety related equipment, the criterion for acceptability is that the modified configuration, when re-evaluated for interactions using the evaluation criteria previously stated, is found to have resolved the original interaction and not created any new interactions.

4.7 DOCUMENTATION CATEGORIES

Each identified interaction will be documented as described in Chapter 5 using the interaction categories previously discussed. The resolution of each interaction will be documented using the following category codes:

R1 - No postulated interactions.

R2 - No standard resolution criteria exists. Analysis to be provided.

R3 - Interacting component to be modified to qualify seismically, or prevent interaction. 3

R4 - Interacting component supported identically to target component.

R5 - Interacting piping component inflicts insufficient target damage as follows: 3

Target pipe at least equal to the nominal pipe size, with wall thickness at least equal to that of the interacting pipe.

R6 - Interacting component inflicts insufficient target damage; analysis to be provided.

R7 - Potential interaction prevented by other components. Secondary interactions not precluded by this criteria.

R8 - Target is located a distance greater than the maximum interacting piping component deflection given in Table 4-5-1.

R9 - Deflection of interacting component prevented by design.

R10 - Potential interaction precluded due to geometry of the equipment layout.

R11 - Leakage insufficient in volume or velocity to compromise the target function or its associated area drain system.

R12 - Interacting component sufficiently distant from target to prevent interaction.

R13 - Target component environment change within acceptable limits.

R14 - Interacting component of insufficient kinetic energy to damage target.

R15 - Electrical power cable contact with target does not affect operability of target.

R16 - Seismic stops, restraints or supports to be added to interacting component to prevent interaction. 3

TABLE 4-5-1

ASSUMED LATERAL DISPLACEMENTS FOR GIVEN SPANS OF SIMPLY SUPPORTED PIPE

3

Pipe Size and Schedule	OD (in)	t (in)	Span Length (ft)	Displacement (in)
1" Sch. 80	1.315	.179	22.7	23.7
1½" Sch. 80	1.900	.200	27.3	23.7
2" Sch. 80	2.375	.218	30.5	23.5
3" Sch. 40	3.500	.216	35.8	22.0
4" Sch. 40	4.500	.237	39.7	21.1
6" Sch. 40	6.625	.280	46.5	19.6
8" Sch. 40	8.625	.322	51.7	18.7
10" Sch. 40	10.750	.365	56.6	17.9
12" Std. Wt	12.750	.375	59.6	16.8
14" Std. Wt	14.000	.375	61.0	16.0
16" Std. Wt	16.000	.375	63.0	14.9

Basis used to develop this table included simple supported span, a stress level of 100% yield, uniform lateral load of 5 times gravity and pipe contents using water.

TABLE 4-5-2

MAXIMUM VERTICAL PIPE SUPPORT SPACING PER B31.1 RECOMMENDED SPACING 3

Nominal Pipe Size (inches)	Maximum Pipe Span (ft.) Water Service	Steam, Gas or Air Service
up to 1	7	9
2	10	13
3	12	15
4	14	17
6	17	21
8	19	24
12	23	30
16	27	35
20	30	39
24	32	42

Note: For intermediate pipe sizes, interpolate between tabulated values.

TABLE 4-5-3

ALLOWABLE KINETIC ENERGY VALUES FOR CLASS I DUCTS AS TARGETS

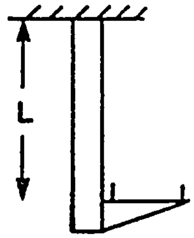
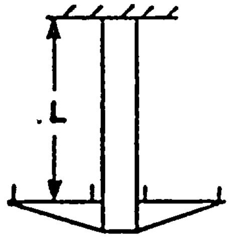
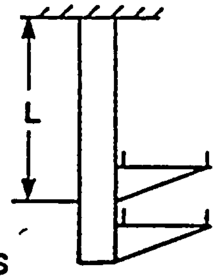
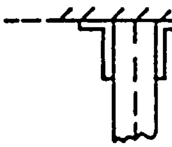
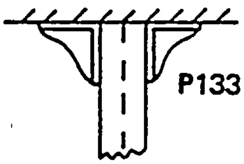
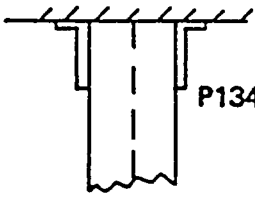
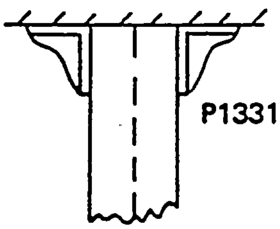
Duct Size Diameter	Span 12"	24"	36"	48"	60"
4"	0.8 in-lb	1.4	1.8	1.8	1.5
6	1.2	2.2	3.0	3.4	3.3
8	0.9	1.8	2.3	2.6	2.6
10	1.7	3.4	4.7	5.7	6.3
12	1.4	2.8	3.9	4.8	5.2
14	1.2	2.4	3.4	4.1	4.5
16	1.1	2.1	2.9	3.6	3.9
18	1.0	1.9	2.6	3.2	3.5
20	0.9	1.7	2.4	2.9	3.1
22	0.8	1.5	2.1	2.6	2.9
24	1.4	2.8	4.0	5.0	5.7
26	1.3	2.6	3.7	4.6	5.3
28	2.1	2.4	3.4	4.3	4.9
30	1.1	2.2	3.2	4.0	4.6
32	1.1	2.1	3.0	3.7	4.3
34	1.0	2.0	2.8	3.5	4.0
36	1.0	1.8	2.6	3.3	3.8
38	1.5	2.9	4.2	5.2	6.1
40	1.4	2.7	4.0	5.0	5.8
42	1.3	2.6	3.8	4.7	5.6
44	1.3	2.5	3.6	4.5	5.3
46	1.2	2.4	3.4	4.3	51.
48	1.2	2.3	3.3	4.2	4.9
50	1.1	2.2	3.1	4.0	4.7
52	2.7	5.3	7.8	10.0	12.0
54	2.6	5.1	7.4	9.6	11.5
56	2.5	4.9	7.2	9.3	11.2
58	2.4	4.7	6.9	9.0	10.8
60	2.3	4.6	6.7	8.6	10.4

Note: An allowable bending stress of 10 ksi has been used in accordance with the SMACNA Code (Sheet Metal and Air Conditioning Contractors National Association, Inc.).

TABLE 4-5-4

SCREENING VALUES OF STRUT LENGTHS

ALLOWABLE L INCHES

			
 P1346 P1001	39	20	20
 P1331 P1001	50	25	25
 P1346 P5001	65	32	32
 P1331 P5001	112	56	56

SYSTEMS INTERACTION PROGRAM

CHAPTER 5 - PROGRAM DESCRIPTION

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CHAPTER 5 - PROGRAM DESCRIPTION

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CHAPTER 5.0 - PROGRAM DESCRIPTION

5.1 PURPOSE

This procedure identifies the general procedures to be followed by the walkdown team in planning, conducting, and reporting walkdowns in their respective disciplines.

5.2 SCOPE

This procedure includes:

a. General definition

b. Example forms for use in identifying those components to be evaluated as a source or target for postulated interactions.

c. Techniques to be used in performing the walkdown.

d. Example forms for reporting postulated failures, interactions and recommended resolutions.

5.3 DEFINITIONS

5.3.1 Component - An individual device in a subsystem. Examples are valves, tubing, wiring, switches, etc.

5.3.2 Important to Safety - Refer to safety related.

5.3.3 Interaction - An unintended contact between a target and a source item. A target item is a structure, system or component important to safety. A source item is any structure, system or component which does not fall under this category. Henceforth, these will be referred to as target and source. In terms of relationship, a source is an item which affects a target. It is assumed that no target item as defined above will fail in a manner as to impact with another target item because the target items have been seismically qualified under other programs.

5.3.4 Operability - Refers to the ability of a target to operate or perform its safety function.

5.3.5 Qualified - Qualified to the Hosgri Seismic Criteria. 3

5.3.6 Safety Function - That action which must be available or performed to accomplish or maintain safe shutdown or to prevent or mitigate the consequences of postulated accidents.

5.3.7 Safety Related - Refers to those structures, systems, or components required to safely shut down the plant, maintain the plant in a safe shutdown condition, and certain accident mitigating systems such as containment isolation, mainsteam isolation and containment spray. The safety related structures, systems, and components are identified in the "Seismic Evaluation for 7.5M Hosgri Earthquake," Amendment 50 to the Diablo Canyon Operating License Application.

5.3.8 Standard Resolution Criteria - That resolution that can be reached in the field by Specific Resolution Criteria as described in Chapter 4.

5.3.9 Subsystem - A collection of components and devices such as valves, sensors and actuation devices which act to perform a specified function or control a specified portion of a system. For example, a valve and all its control devices are a subsystem. The subsystem will be identified by the identification of the controlled device. 3

5.3.10 System - The interconnected components and subsystems which act to perform safety functions. A system will be defined as available if it is intact and operational. To be intact, the required flowpath must have no failures, the desired flowpath open, and the undesired flowpaths isolated. To be operational, a system must be controllable to the extent required by the functional design. For example, all required pumps must be capable of being run or stopped, and all valves which must be operated must be capable of being operated as required. All indicators needed by the operator to assess the operation of the system must work. 3

5.4 PRE-WALKDOWN PLANNING

5.4.1 Safety-Related Functions and Systems Matrix

The first step is to identify the safety functions that must remain operative during and following an earthquake. If the safety functions are assured, the plant systems will be capable of achieving and maintaining safe shutdown and of preventing or mitigating the consequences of postulated accidents. The single active failure criterion will continue to be satisfied.

Each safety function will be identified as being required for a specific safety purpose or purposes.

Following identification of each safety function, a list of those systems which are responsible for performing that function will be generated. This list forms the basis for the system matrix. 3

Most safety functions can be performed by more than one system. In such cases, all systems will be identified. The redundancy to compensate for single failures will be maintained.

All disciplines will be reviewed for each safety function to ensure that all of the associated systems have been included.

5.4.2 System Matrix

For each target system identified, a System Matrix will be completed, as shown in Table 5-1. In each System Matrix, all of the subsystems required for the operability of that system will be listed and numbered sequentially, by safety function and subsystem numbers.

The operating requirements for each subsystem will also be listed. In general, these will be statements like fail open, fail closed, operate (open and close), run, etc.

5.4.3 Subsystem Matrix

A subsystem Matrix, as shown in Table 5-2, will be completed for each subsystem listed in Table 5-1.

With required safety functions and related target systems identified, a system-by-system review will be performed based on the work done for the Hosgri evaluation to determine all the components, necessary to ensure the performance of the required safety functions.

SYSTEMS INTERACTION PROGRAM

The Subsystem Matrix identifies each component required to ensure the operability of their associated target system.

Each item of equipment will be, in general, a part of a control circuit, a power circuit (electric or pneumatic), or a fluid flowpath.

Each of these circuits or flowpaths for each item will be examined separately and traced to its origin. Each item of equipment including the pathway (pipe or cable) will be considered and categorized in order to establish which equipment must be protected.

Each component in the Subsystem Matrix will be listed and numbered sequentially, by safety function, subsystem, and component numbers. A prefix identification will be that which is used to identify the device in the field.

For a cable in a cable tray or conduit, both the cable and tray identifications shall be used.

The safety class of the component and the fire area location of the component shall also be listed.

For components (e.g., cables) which involve more than one fire area, all applicable fire areas shall be listed.

Fire zones shall be listed by identification number. 3

5.5 WALKDOWN PROCEDURE

1. The Interdisciplinary Team begins a walkdown in a compartment within a fire zone as follows:

    a. Identify components to be evaluated.

    b. Walk down each target subsystem and evaluate for interactions using the criteria described in Chapter 4. Evaluate each component and trace all associated power and instrumentation lines to the boundaries of the compartment.

    c. Check off each subsystem and component on the applicable matrix to ensure that evaluation was completed. Note areas where further tracing of power or instrumentation lines is required.

2. Each item of equipment involved in the safety function is successively considered together with its control and power circuit, whether pneumatic or electric. When a particular item of equipment is found to be necessary to perform the safety function, the power and control circuits for that item will be traced to their origins. This includes all equipment that must perform a safety function and, therefore must be protected from detrimental interactions with source equipment. The detrimental interactions may be mechanical, electrical, pneumatic, hydraulic, or environmental. 3

3. During the walkdown, it will be necessary to determine if a component in a fire area is subject to any of the following hazards.

    a. Direct physical contact by failure of source equipment.

    b. Direct physical contact due to vibration of source equipment.

    c. Jet impingement from failure of a source-type high energy line.

d. High temperature, pressure or humidity due to failure of source-type high energy lines.

e. Flood due to failure of source-type piping, causing a leak greater than the capacity of the drain system.

f. Any other hazards that become apparent.

4. Inspect each item to be evaluated in a given fire zone. All interaction sources in the vicinity of the item being evaluated are postulated to fail or be displaced in various ways in accordance with the source failure criteria of Chapter 4.

Once a potential interaction associated with a particular component is identified, it is discussed among the cognizant Walkdown Team Members and documented on an Interaction Documentation Sheet (see Table 5-4) as follows:

a. Identify the fire zone by number, the location by elevation and physical description within the compartment, and the Postulated Interaction Number which is comprised of the component matrix number and a sequence number indicating the total number of interactions associated with the particular matrix item.

b. Identify the source and target components as completely as possible, utilizing line numbers, instrument numbers, etc., whenever possible.

c. Describe the nature of the interaction; i.e., explain the source interaction relative to the target.

d. Following discussion with the Walkdown Team Members, describe the recommended resolution of the postulated interaction, i.e., source analysis, plant modification, etc., or the rationale used for immediate (on site) resolution requiring no further action.

e. Sign and date the Interaction Documentation Sheet.

5. Repeat the above for all compartments within a particular fire zone and for all fire zones.

5.6 DOCUMENTATION

5.6.1 Data Base (Table 5-3)

As the walkdown phase of the program progresses, the Data Base forms of Table 5-3 will be filled out for each postulated interaction. 3

5.6.2 Subsystem Matrix (Table 5-2)

The Subsystem Matrix is completed before each walkdown to assist the Walkdown Team with component identification and associated information such as failure modes. Any observations pertaining to the seismic behavior of a component is described under the "notes" column.

5.6.3 System Matrix (Table 5-1)

After the subsystem matrix is completed, the failure mode of the subsystem is determined for the nonpower and power conditions by detailed systems analysis. These failing modes are both placed into the system matrix and compared with the desired operability requirements for that particular system.

If a failure mode of a subsystem is not obvious from examination of the subsystem matrix, a reference to an analysis or explanation shall be given. 3

5.7 REVIEW AND INTERACTION RESOLUTION

5.7.1 System Evaluation

After the System Matrices are completed, it must be confirmed that the safety function will be available. This is accomplished by reviewing the operability requirements of the system and verifying that subsystem failure modes and interaction resolutions are such that the safety function is deemed available.

5.7.2. Interaction Resolution

Postulated interactions will fall into one of the following categories:

a. The interaction will not occur.

b. The interaction could possibly occur. Therefore:

  (1) The results of the interaction are inconsequential, or

  (2) The results of the interaction are consequential; thus, one or more of the following may be required:

    (a) Target reinforcement

    (b) Source reinforcement

(c) Shielding between target and source

(d) Seismic qualification of source components and structures by analysis.

(e) Source or target relocation. 3

Those items which cannot be reasonably qualified by analysis will be qualified by other methods such as testing, past seismic performance which is carefully documented and determined to be applicable, or engineering judgment.

All interaction resolutions will be documented and any required plant modifications will be initiated. All plant modifications will be inspected to ensure 1) proper resolution of the postulated interaction and 2) that no new interactions were created by the modification.

5.8 FINAL REPORT

A final report will be prepared which compiles all walkdown data, interaction resolutions and technical reports.

TABLE 5-1

SYSTEM MATRIX

Page ____ of ____

Matrix No. ____________ Function ____________ System ____________

No.	Subsystem	Desired Operability Requirements	Failure Mode With Power	Failure Mode Without Power	Comments

TABLE 5-2

SUBSYSTEM MATRIX

Page ___ of ___

Matrix No. ____________________ Subsystem No. ____________________

Component	Identification	Location Matrix	Safety Class	Failure Mode With Power	Failure Mode Without Power	Notes

TABLE 5-3

COMPUTERIZED DATA BASE

1.0 PURPOSE

These entry forms attached are completed for the purpose of recording both walkdown findings and the status of any action which is taken as a result of these findings.

Specific forms and guidelines for their completion are provided to facilitate direct computer entry and retrieval of this data.

2.0 APPLICABILITY

All findings made on the walkdown will be recorded on a Records Management System (RMS) coding form. The information from these coding forms will be executed into a computer.

3.0 PROCEDURE

3.1 A System Interaction Program Data Entry Form is to be completed for each unique matrix number. The System Interaction Program Data Entry Continuation Form is to be used when more space is needed.

3.2 The appropriate dictionary is to be used to select terms to enter in the boxes provided. At the beginning of each category, the specific dictionary is listed for reference.

a. New terms which are not in the appropriate dictionary may be entered in the boxes when they meet the guidelines for the kind of information to be entered in that category.

b. New terms are to be circled on the entry form.

c. Place two commas between each term, and use the continuation sheet when enough space is not provided on the form.

TABLE 5-3

PG-E
Quality Assurance
76-685D Rev. 6/79

RECORDS MANAGEMENT SYSTEM DOCUMENT INDEX CODING FORM D

PAGE 1 OF ____

(For use with documents being entered into the RMS for the first time)

Data Recording Format 388

M = MANDATORY ENTRY
T = TECHNICAL INDEXER

TO:
RECORDS MANAGEMENT CENTER
Rm. 2420, 77 BEALE ST.

PART A RETURN TO:

Department Representative ____ Dept. ____

Room ____ Address ____

(Circle Proposed New Legal Terms)

CHECK BOX TO CONTINUE ON FORM E

PART B
INDEX CATALOG (1–2) (DC, HB, ST, NG) FILM REF. No. (3–7)–(9–12)

SEARCHABLE CATEGORIES WITHIN INDEX CATALOG

	Field	No.	Columns	Entry	Continue
	PGENO (Level 5)	1.	15–45		1. ☐
	REV	2.	48–51		
	DAT (YR MO DAY)	3.	54–59		
MT	TYP (Doc. Type)	4.	62–92		4. ☐
T	SNO (System Number)	5.	95–125		5. ☐
T	CMP (Component)	6.	128–158, 159–189, 190–220		6. ☐
MT	DSCR (Descriptors) (Level 6)	7.	15–45, 46–76	UNIT	7. ☐
M	ORIG (Originator)	8.	79–109		8. ☐
	RCPT (Recipient)	9.	112–142		9. ☐
	SUPNO (Supplier No.)	10.	145–175		
	UDFNO (File No.)	11.	178–208		11. ☐
	RLOC (Record Location)	12.	15–45		

NON-SEARCHABLE WITHIN INDEX CATALOG

	Field	No.	Columns	Entry	Continue
	RMK (Remarks) (Level 7)	13.	48–78, 79–109		13. ☐
	ACS (Access)	14.	110		

PART C – ADDITIONAL COMMENTS ____

M PART D – RESPONSIBILITY

Completed By:

Non-Technical Indexer(s) ____ Ext. ____ Date ____

RI/Technical Indexer ____ Ext. ____ Date ____

Checked by: Dept. Rep. ____ Ext. ____ Date ____

PART E – RECORDS MANAGEMENT'S COMMENTS TO USER:

☐ Entry into RMS is complete. ☐ Microfilm is unacceptable. ☐ Incomplete Index Form.
☐ Corrections have been made: ☐ per RM request; ☐ per your request. ☐ Record is not applicable. ☐ Please resubmit.
☐ Record has not been entered into the RMS. ☐ Other ____
Reason ____

PART F – FOR RECORDS MANAGEMENT SECTION INTERNAL USE ONLY

Checked ____ Auth Maint ____ Entered ____ Verified ____ Film Rec'd ____ Entry Appr'd ____ Date Ret ____

TABLE 5-3 (Cont.)

Form #S-1

SYSTEM INTERACTION DATA ENTRY FORM
CRITERIA RESPONSE SHEET
FOR DSCR CATEGORY

GUIDELINES FOR USE OF THIS SHEET:

Use this sheet to record the response to each criteria in the DSCR category. Enter the response immediately following the criteria number. Only one of three possible responses may be entered:

Y for YES
N for NO
X to indicate that the criteria does not apply

CATEGORY
DSCR 7

CRITERIA NO	CRITERIA NO	CRITERIA NO	CRITERIA NO	CRITERIA NO
PF1__	MF1__	EF1__	RF1__	R1____
PF2__	MF2__	EF2__	RF2__	R2____
PF3__	MF3__	EF3__	RF3__	R3____
PF4__	MF4__	EF4__	RF4__	R4____
PF5__	MF5__			R5____
PF6__	MF6__			R6____
PF7__				R7____
PF8__				R8____
				R9____
				R10___
				R11___
				R12___
				R13___
				R14___
				R15___
				R16___

CRITERIA NO	CRITERIA NO	CRITERIA NO
HF1__	CF1__	IF1__
HF2__		IF2__
HF3__		
HF4__		
HF5__		
HF6__		

TABLE 5-4

PACIFIC GAS & ELECTRIC CO.
DIABLO CANYON PLANT
SEISMICALLY INDUCED SYSTEMS INTERACTION PROGRAM
INTERACTION DOCUMENTATION SHEET
(Use additional sheets if required)

Fire Zone:

Location within Fire Zone:

Postulated Interaction No.:

Identification of interacting components including operating mode/position, etc.:

Description of Postulated Interaction:

Recommended Resolution of Postulated Interaction:

Final Resolution of Postulated Interaction:

SISIP Discipline Supervisor
(Applies only if resolution is required.)

Originator/Date

Reviewer/Date

SYSTEMS INTERACTION PROGRAM

CHAPTER 6 - RESOLUTION

TABLE OF CONTENTS

LIST OF TABLES

SYSTEMS INTERACTION PROGRAM

CHAPTER 6 - INTERACTION RESOLUTION PROCEDURE

6.1 PURPOSE

This procedure describes the general procedures to be followed in resolving the postulated interactions identified by the Systems Interaction Walkdown Team.

6.2 APPLICABLE DOCUMENTS

6.2.1 Interaction Documentation Sheet

This sheet describes the postulated interaction observed during the walkdown. (A copy of this form is included as Table 5-4 or page 5-17.)

6.2.2 Interaction Log and Resolution Status

This weekly report 1) assigns the postulated interaction to either a Company Discipline or a Consultant for the engineering resolution of the postulated interaction, and 2) documents the percent complete of the resolution work for each interaction. (A copy of this form is included as Table 6-1 on page 6-4.)

3

6.2.3 CCS Task Report, Form CC-1

This form shall be completed for each interaction requiring further resolution work. The Form CC-1 shall be filled out by personnel under the direction of the Supervisor of Program Coordination and routed through the Project Control Engineer's Office for assignment. The CCS Task Report system facilitates the monitoring of the resolution effort. (A copy of this form is included as Table 6-2 on page 6-5.)

6.3 ENGINEERING AND REVIEW

Design changes shall be handled in accordance with Procedure 3.6 and other relevant procedures of the Engineering Manual. In addition, when the postulated interaction resolution task has been completed by the Company Engineering Discipline or Consultant, a copy of the engineering resolution with accompanying drawings, sketches, and calculations shall be submitted to the Systems Interaction Project Engineer for review by the Technical Consultant. This review shall be performed concurrently with the normal process of issuing designs to the field and shall be completed before field implementation of any resolution work requiring major plant modification.

6.4 CONSTRUCTION

Field modifications associated with interaction resolutions shall be handled in one of two ways. 3

6.4.1 Minor changes that do not require any drawing revisions may be handled directly between General Construction and the affected Cognizant Discipline Engineer by memo. A copy of the General Construction work request or other proof of completed work shall be sent to the Systems Interaction Project Engineer so an audit can be arranged.

6.4.2 All other changes shall be in strict accordance with the Engineering Manual Procedure 3.6 Design Changes. When the field changes are complete, a copy of completed work request shall be sent to the Systems Interaction Project Engineer so an audit can be arranged.

6.5 AUDIT

An audit shall be made of all required field changes. The audit team will consist of the Cognizant Discipline Engineer from the affected discipline, the Systems Interaction Technical Consultant, and at least one other member of the Systems Interaction Walkdown Team. Written results of the audit shall be forwarded to the Systems Interaction Project Engineer. 3

6.6 DOCUMENTATION

An individual file shall be established for each postulated interaction. All related documents shall be placed in this file which is maintained by the Program Supervisor. When the interaction resolution work is completed and audited, the entire file shall be turned over to the Records Management System (RMS) Unit for microfilming.

TABLE 6-1

PACIFIC GAS AND ELECTRIC COMPANY
DIABLO CANYON PLANT
SEISMICALLY INDUCED SYSTEMS INTERACTION PROGRAM

INTERACTION LOG AND RESOLUTION STATUS

NAN = No Action Necessary

RLCA = Robert L. Cloud Associates, Inc.

EDS = EDS Nuclear

DCSIS = System Interaction

ICE = Instrumentation & Control

PSE = Piping

EMS = Mechanical Systems

EE = Electrical

CE = Civil/Structural

INTERACTION NUMBER	RESOLUTION ASSIGNED TO	RLCA INITIAL REVIEW/DATE	%COMPLETE DATE	RLCA FINAL REVIEW/DATE

3

76-353

NEW TASK ☐
CHANGE ☐

Table 6-2

CCS TASK REPORT
COMMITMENT CONTROL SYSTEM

PCE USE ONLY
Task No.
Date Entered
Priority
Req. Compl. Date
Sch. Act. No.

Page 1 of ______

Unit No. ____________________ Group ID ____________________

______________________________, ______, ______
Responsible Person

Is Construction Required   Yes   No   Unknown

Is Licensing Effected   Yes   No   Unknown

Task Description ____
____
____
____
____

Initiating Document ____
____

Estimated Manhours ____________________ Units of Work ____________________

Estimated Manhours Available Per Week ____________________

Estimated Start Date ____________________ Estimated Completion Date ____________________

CONSTRAINTS

Predecessors	Successor

Comments ____________________
____
____
____
____

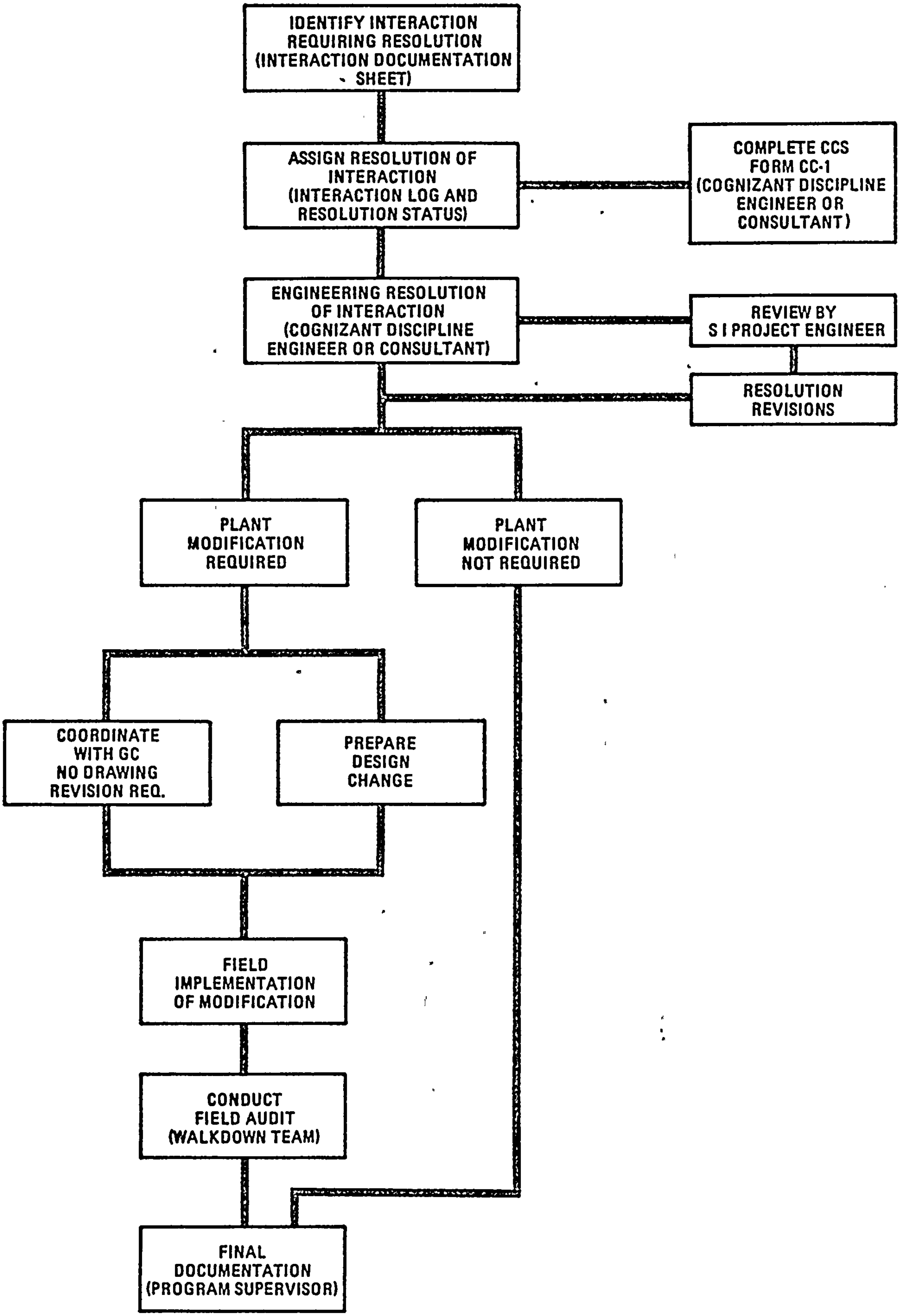
______________________________, ______
Responsible Person   Date

______________________________, ______
Approved Task Leader   Date

____
Originating Person

CC-1 (3/10/80)

TABLE 6-3



INTERACTION RESOLUTION PROCEDURE